Alternative: Restore and Manage Forests, Piñon-Juniper Woodlands, and Riparian Systems

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1. Summary of the Alternative

The alternative addressed in this white paper looks at the management of three distinct ecosystems: forests, piñon-juniper woodlands, and riparian systems. For the purpose of this white paper, these ecosystems are defined as follows:

- Forests are the areas dominated by conifers and aspens. In general, the forest zone can be broken up into three main vegetation types: (1) the lower-elevation ponderosa pine zone, (2) the middle-elevation mixed conifer zone, and (3) the upper-elevation zone dominated by spruce or aspen.

- Piñon-juniper woodlands are those areas where the overstory is dominated by piñon pine, juniper, or both.

- Riparian zones technically occur along all streams and rivers, but for the purpose of this white paper the term "riparian systems" will only refer to the areas along lower-elevation intermittent or perennial streams below the forest zone. Riparian zones within the forest are explicitly or implicitly included in the discussion of the management options in forested areas.

The focus of this alternative is assumed to be the potential to increase water yields through vegetation management. However, the potential for increasing water yields cannot be separated from the potential effects on runoff processes, erosion, and water quality. Hence the discussion of management alternatives includes an assessment of the potential positive and negative effects on water quality.

The potential increase in yield will increase the amount of wet water available for existing water rights in the region. This alternative is not considered as one that will provide new water to meet growing demand, but rather as an alternative that protects and restores existing water supplies (and ecosystems), thus reducing the need to purchase additional water supplies.

In the past couple of decades forest density has generally increased due to the suppression of fire and the limited amount of timber harvest. This has almost certainly resulted in a decrease in water yields. Management activities such as forest harvest or thinning could potentially increase water yields. In addition, reducing vegetation density can help lower the risk of severe wildfires. As seen in the case of the Cerro Grande and numerous other fires (Robichaud et al., 2000; Moody and Martin, 2001), high-severity fires can greatly increase the size of peak flows and surface erosion rates, increase channel erosion, cause downstream sedimentation, and adversely affect water quality.

In the piñon-juniper zone there also has been a general increase in tree density, as well as a corresponding reduction in the abundance of forbs and grasses. Past management practices have focused on reducing woody vegetation and increasing the amount of forbs and grasses, but increases in herbaceous vegetation have generally been short-lived. Efforts to reduce the amount of woody vegetation will have a negligible effect on water yields, as the annual precipitation is simply too low; any reduction in transpiration will be lost to a corresponding increase in evaporation (e.g., Bosch and Hewlett, 1982). Changes in the intensity of grazing could potentially affect the partitioning of rainfall between surface runoff and infiltration and, hence, the amount of hillslope and riparian erosion, as well as water quality, channel morphology, and aquatic habitat.

In the riparian zones the two primary management issues are grazing and the invasion of exotic species. Grazing practices would have little or no effect on water quantity, but can have a much bigger effect on water quality than efforts to control exotic species. The control of exotics is primarily an ecological issue and cannot be expected to greatly affect either water quality or water quantity within the Jemez y Sangre region.

2. Technical Feasibility

2.1 Restore and Manage Forests

The management activity with the greatest potential to increase water yields is to reduce forest density. In general, water yield increases are proportional to annual precipitation and the proportion of the forest canopy (usually expressed in terms of basal area) that is removed (Bosch and Hewlett, 1982; Troendle and Kaufmann, 1987). Little or no water yield increases can be expected in areas where annual precipitation is less than about 450 to 500 mm (18 to 20 inches) (Ffolliott and Thorud, 1975; Bosch and Hewlett, 1982; Stednick, 1996) or in areas at or near timberline, where there is insufficient vegetation to make transpiration a dominant source of water "loss."

Research in Colorado has shown that water yield increases in the higher elevation lodgepole and spruce-fir forests are directly proportional to the amount of basal area that is removed (Troendle and King, 1987). However, limitations in the accuracy of streamflow measurements and the regressions between paired basins means that at least 20 to 25 percent of the basal area within a watershed must be removed in order to detect a statistically significant change in runoff (Troendle and King, 1987; Troendle et al., 2001). Smaller reductions in basal area would be expected to increase streamflow, but one cannot expect to measure these predicted increases.

The large variability in annual precipitation is another important limitation to managing forests for water yield. Water yield increases are directly proportional to precipitation, and the coefficient of variation for annual rainfall for forested areas in and around the study area is close to 25 percent (DE&S, 2001). Data from the Fool Creek study in central Colorado showed that water yield increases in dry years were only about one-quarter of the increases in wet years (Troendle and King, 1985). This means that water yield increases from forest harvest would be least in the dry years, when they are most needed, and greatest in the wet years, when they are least needed. The presence of storage reservoirs with sufficient capacity to carry over excess water from wet years is therefore an important factor in determining whether forest management is a feasible option for increasing water yields.

It also is important to recognize that most of the increase in water yield in snow-dominated areas comes on the rising limb of the snowmelt hydrograph. At Fool Creek in Colorado, May was the only month with a statistically significant increase in monthly water yields (Troendle and King, 1985). Paired watershed experiments in areas with more substantial amounts of summer rainfall have sometimes yielded large increases in summer runoff in percentage terms, but the amounts are very small in absolute terms (e.g., less than 0.1 cubic feet per second [cfs] per square mile) (Austin, 1999). Again this suggests that some storage will be required if most of the harvest-generated increases in runoff are to be used between the beginning of July and approximately mid-April.

Another technical limitation for increasing water yields is the fact that the increased water yields diminish as the forest regrows. Long-term data from the Fool Creek study suggest that approximately 60 to 70 years are required for water yields in the subalpine zone to return to pre-harvest levels (Troendle and King, 1985). The recovery rate for aspen, however, is substantially shorter. In the Wagon Wheel Gap paired watershed study, the increase in water yield disappeared within a few years due to a series of dry years and rapid regrowth of aspens (Bates and Henry, 1928; C. Troendle, 1983, U.S. Forest Service, personal communication, 2000). More recent modeling efforts have assumed that aspen reaches full hydrologic recovery in 30 years, although the potential range is from 15 to 45 years (Troendle and Nankervis, 2000). The hydrologic recovery associated with forest regrowth means that the average, long-term increase in water yield is much less than the water yield increase observed in the first few years after treatment (Rector and MacDonald, 1987).

In summary, the average long-term increase in water yield depends on the annual precipitation, the species being treated, the proportion of the canopy that is removed, the regrowth rate, and the length of time between treatments. The timing of the increase in runoff may not match up well with the timing of peak demand, so some storage capacity may be required to obtain the full benefits of any projected increase in streamflow.

These principles mean that the greatest potential for increasing water yields is in the higher-elevation spruce forests. The aspen and mixed conifer forests have a more limited potential for increasing water yields because of the lower annual precipitation and the more rapid hydrologic recovery of aspen sites.

The smallest potential for increasing water yields is in the ponderosa pine forests. In these drier sites the remaining vegetation and soil evaporation will take up more of the water that is "saved" by the reductions in interception and transpiration, and less regrowth will be needed before the site has hydrologically recovered. Observed increases in flow from the harvest of ponderosa pine stands in other areas has ranged from zero to a maximum of 2 inches per unit area (Rich, 1972; Brown et al., 1974; Ffolliott and Thorud, 1975; Gary, 1975; Troendle, 1983). A recent study of the potential for increasing water yields in north-central Colorado assumed that harvesting ponderosa pine would result in no net increase in water yield (Troendle and Nankervis, 2000). Reiland's (1976) study of annual water yields in the Pojoaque basin assumed that areas below about 9,000 feet generated, on average, less than 1.0 inch of annual runoff per unit area.

An extensive program of forest harvest or thinning could increase erosion rates and adversely affect water quality as a result of increased turbidity and sediment loads. The magnitude of these effects will depend more on the methods used to yard and remove the woody material than on the harvest itself, as roads and skid trails are the primary sources of sediment from well designed and carefully executed forest management programs. To minimize the increase in erosion from the harvested areas and impacts on water quality, best management practices, including the use of buffer strips along both perennial and ephemeral streams, should be applied.

Prescribed fire would not be expected to cause an increase in water yields because most prescribed burns are designed to remove only the brush and suppressed trees, not to extend into the crowns and kill the larger overstory trees. In some cases small patches of high-severity burns may occur, but there is little reason to expect an increase in water yields unless there is a substantial reduction in basal area. Because prescribed fires typically do not burn all of the protective litter and humus layer and do not result in large patches of water-repellent soils, prescribed fires are not expected to cause a significant increase in runoff or adversely affect water quality (Tiedeman et al., 1979; Robichaud and Waldrop, 1997).

Two key limitations to the increased use of prescribed fire are the limited meteorologic windows for conducting prescribed burns and the amount of smoke and particulates generated from prescribed fires. Prescribed fires require conditions that are dry enough to burn, but sufficiently wet so that the fire has relatively little risk of escaping and causing unwanted damage. Only a few days each year may be suitable for igniting a controlled burn, and the limited number of trained personnel constrains the amount of area that can be treated at one time. The production of particulates is a concern for both public health and visual air quality. Both of these issues may pose serious constraints to the initiation of larger-scale prescribed burning programs.

In the absence of any efforts to reduce forest density, one can expect a continuing high risk, or a gradual increase in risk, for high-severity wildfires. High-severity fires are of considerable concern because of the potential to destroy property and greatly increase runoff and erosion rates (Robichaud et al., 2000; Moody and Martin, 2001). These increases can then have severe effects on downstream channels, aquatic habitat, and reservoir sedimentation rates. Wildfires in the forested portion of the study area are a very real threat, but because these are the result of inaction rather than a specific management activity, they will not be discussed further.

2.2 Restore and Manage Piñon-Juniper

The opportunities for management actions to affect water yields and water quality in the piñon-juniper zone are much more limited than in the forested areas. There is virtually no opportunity to increase water yields through removal or reductions in the tree canopy, as the annual precipitation in this zone is less than 450 mm. However, some improvements in the ecological health of the area and the timing of runoff events can be expected. The critical issue with respect to runoff and erosion is the amount of cover and surface roughness in the intercanopy areas. Hence the effect of increasing tree density on water quality can vary, but runoff and erosion rates are generally less under the tree canopy than in the intercanopy areas (e.g., Reid et al., 1999). Increased fuelwood harvests would probably have minimal effects on runoff, but the corresponding increase in herbaceous vegetation could improve water quality. A decrease in water quality could occur if there is substantial ground disturbance associated with the tree cutting and increased vehicle traffic.

In one example near Ruidoso, dramatic changes in streamflow were observed after removal of piñon-juniper from a property. The dry, downcut arroyos became perennial streams. The newly established grass held the moisture, reducing the peak of the hydrograph and allowing the runoff to occur over a longer time. While no more runoff may occur on an annual basis, the nature of the runoff is drastically changed. This effect, however, is highly site-specific and depends on a variety of factors such as soil depth, changes in ground cover, slope, bedrock type, and precipitation.

With respect to runoff and water quality, the most significant management issue in this zone is the intensity, timing, type, and location of grazing activities. Although the effects of grazing can be highly variable, the scientific literature generally indicates that high-intensity grazing causes a significant reduction in plant cover and infiltration rates, potentially leading to increased runoff, an increase in surface erosion, a decrease in site productivity, and a decline in water quality (Blackburn et al., 1982; Trimble and Mendel, 1995; Belsky et al., 1999).

Cattle tend to concentrate in riparian areas within the piñon-juniper zone because of the better forage, water for drinking, and shade. The concentration of cattle in the riparian areas usually has a more direct and largely adverse effect on aquatic resources than high-intensity grazing outside the riparian area, as the delivery of sediment and animal wastes into the stream channel is much more direct. The concentration of cattle or other animals in riparian areas and the resultant trampling and reduction of riparian vegetation can also destabilize the streambanks and further increase the amount of sediment being delivered to the stream. The large number of studies on grazing have reached varying conclusions, but the general consensus is that heavy grazing can have relatively severe effects on runoff, erosion, and stream channels, while light to moderate grazing has much less effect in terms of soil compaction, surface erosion, and degradation of riparian areas and stream channels.

The adverse impacts of grazing within the study area have been noted by the U.S. Forest Service, other agencies, and private consultants (e.g., USFS, 1987; Wirtz, 1998). Some of these effects can be alleviated by simply reducing the number of animals, but the total number of animals is often not as much of a problem as the distribution of animals within the areas being grazed. A combination of fencing, herding, and the provision of salt and watering points away from the stream can help ensure a more even distribution of grazing pressure and reduce the concentration of animals in the riparian zone. The use of such management techniques could be expected to have a beneficial effect on riparian health and water quality. However, quantitative estimates of the likely change for a given change in management are extremely difficult to provide.

An important limitation to a better match between site productivity and the number of grazing animals is the interannual variability in the amount and quality of forage. In dry years a given parcel of land can support fewer animals than in wet years, but it is very difficult for landowners to rapidly adjust the size of their herds in response to short-term changes in range productivity. The social and economic issues associated with changes in grazing management are discussed in Section 7 of this paper.

2.3 Restore and Manage Riparian Zones

The two main issues with respect to the restoration and management of riparian zones are the control of grazing and the control of exotic species. Both of these issues also apply to the riparian areas in other zones, particularly the piñon-juniper zone. The same issues of grazing in riparian areas discussed in Section 2.2 also apply to the lower-elevation riparian zones.

The control of exotic species is a concern primarily for ecological reasons rather than the effect of exotic species on water quantity or water quality. Recent studies indicate that exotic species such as salt cedar *(Tamarix ramosissiama* [tamarisk]*)* use similar amounts of water per unit leaf area as native woody riparian species (e.g., Sala et al., 1996; Smith et al., 1998). If tamarisk has more leaf area on a stand basis than the native riparian species, or if it can occupy areas that are too dry or too saline for native woody riparian species, the shift from native riparian species to tamarisk could result in a decrease in water yields.

This suggests that in some cases the removal of tamarisk might increase water yields per unit area, but the question then becomes whether the size of the treated area is large enough to cause a significant change in water yields on a watershed basis. In many cases the total area of riparian vegetation is only a small proportion of the total area of a watershed and it may not be possible to treat all of the riparian zones within a watershed, so the control of exotic species will not have a significant effect on water yields at the watershed scale in the Jemez y Sangre region.

The similarities in water use per unit leaf area between natives and exotics also suggest that the greatest potential increase in water yields will result from changing a dense, woody vegetation dominated by tamarisk to an open savannah with only scattered native woody riparian plants. The actual magnitude of a change in water yields will depend on the species involved, soil type, depth to groundwater, amount of woody versus shallow-rooted vegetation, and the relative dependence of each vegetation type on groundwater, precipitation, and soil moisture.

The effects of exotic species on bank erosion and water quality are not as clearly documented, even though many of the exotic riparian species were introduced for erosion control purposes. The high density of tamarisk stands probably increases the amount of overbank deposition, and this should reduce downstream sediment loads and possibly even improve downstream water quality.

In general, the primary concern with exotic species is their ecological effect, particularly the extent to which exotic species reduce the amount and quality of riparian habitat available for other key species, such as the southwest willow flycatcher. Even though the riparian areas are a small percentage of the Jemez y Sangre region, they provide habitat for a large number of species, and community-based riparian restoration projects may be beneficial in preserving biodiversity. These issues are discussed in more detail in Section 6.

3. Financial Feasibility

Efforts to reduce vegetation density and increase water yields in the forested zones will generally require a net investment of public funds. Commercial timber sales have not been offered over the past 15 to 20 years due to environmental concerns and public opposition, and the lack of timber from public lands has probably contributed to the closure of several small sawmills that traditionally processed small-diameter products.

In flatter areas (e.g., less than 30 percent slope) with an existing road network, it may be feasible to commercially thin some forest stands, but much of the marketable timber is in the Pecos Wilderness or the Santa Fe Municipal Watershed. In most areas, however, non-commercial thinning would have to be carried out. In areas with road access, costs for non-commercial thinning would be approximately $250 to $500 per acre; in steeper areas and areas without an existing road network, the costs would be considerably higher. For example, the estimated cost of treating the Santa Fe watershed is approximately $1,000 per acre, due in part to the steep slopes. In addition, the $250- to $500-per-acre cost range includes physical treatments only; costs for planning, conducting environmental (i.e., NEPA) studies, or treating the slash can make the overall cost of the project significantly higher.

The lack of local mills means that the primary uses of the thinned material would be for poles, posts, or fuelwood. If there is not a commercial market for the harvested material, the thinnings would have to be chipped and scattered, piled and burned, or broadcast burned. Lopping and scattering costs approximately $55 to $65 per acre, while the cost of chipping and scattering is slightly less. Piling costs around $65 to $75 per acre, and burning slash piles costs another $26 to $35 per acre, depending on the number, size, and accessibility of the slash piles. Prescribed fire, or broadcast burning after thinning, is the cheapest treatment at $9 to $12 per acre.

Piñon-juniper areas are used primarily for fuelwood and livestock production. Past practices included chaining followed by seeding, but this was costly, induced severe erosion in some areas, and was subject to considerable public resistance. Broadcast burning is generally not feasible because there is not enough fuel to carry the fire during the conditions conducive for well controlled burns. Overall, the costs of trying to alter or intensively manage these areas have far exceeded the potential return, and these practices have thus been largely discontinued.

Costs for a new, four-wire fence to control grazing are approximately $3,500 to $4,000 per mile. Grazing permittees on federal land average only 22 to 25 head of livestock per household, and this simply doesn't provide enough income to support major changes in management.

Simple removal of the exotic overstory in riparian zones costs from $45 to $55 per acre, but multiple treatments may be required to completely eliminate the exotic species. In many cases it could cost much more to re-establish a functioning riparian zone with native riparian vegetation, as many streams and rivers have been subjected to substantial alterations in channel morphology and their natural flow regimes (National Research Council, 1992). In such cases, extensive earth moving may be required to establish a functional channel and floodplain at the appropriate elevation relative to the existing flow regime and sediment load and thereby restore the natural processes such as overbank flooding and sediment deposition. These areas often have to be planted and seeded, and relatively intensive efforts to control exotic species may also be required, particularly in the first few years after planting.

A high proportion of the riparian and piñon-juniper vegetation types are either in private ownership or under Pueblo jurisdiction. The control of exotic species, the restoration of riparian areas, and the implementation of an aggressive range management program all represent substantial expenditures with relatively small financial returns, at least in the short or medium term, and some kind of financial assistance program will therefore be necessary if significant areas are to be treated or restored.

4. Legal Feasibility

The focus of this legal paper will be management of high-elevation forests, which present the greatest opportunities for increased water yield, rather than piñon-juniper or riparian forests.

Two different types of legal requirements affect implementation of this alternative. The first type is the laws, mostly federal, that govern what you can do to land and trees and surface waters and how you can do it. These laws place constraints on how you carry out forest management activities. Presumably, most lands that would be affected by high-elevation forest management would be in national forests or national forest Wilderness Areas, although it is possible that some such lands might be within national parks or monuments (e.g., Bandelier). Since no roads, commercial enterprises, or motorized equipment are permitted in Wilderness Areas, little significant forest management can occur in those areas, other than non-invasive fire management.

In the national forests, any management actions taken to increase water supply emanating from the forests must comply with a number of federal laws, including the National Forest Management Act, 16 U.S.C. §1600, *et seq.* (NFMA), the National Environmental Policy Act, 42 U.S.C. §4321 *et seq.* (NEPA), the Clean Water Act, 33 U.S.C. §1251 et *seq.* (CWA), the Endangered Species Act, 16 U.S.C. §1531 *et seq.* (ESA), and possibly the National Historic Preservation Act, 16 U.S.C. §470 *et seq.* (NHPA) and the American Indian Religious Freedom Act, 42 U.S.C. §1996 (AIRFA). Most of the constraints placed by these laws relate to process, studies, and planning that must be done before significant surface-disturbing work is done. There will, however, also be substantive constraints on how much logging and road-building can be done. NFMA (and its regulations) places limits on methods and locations of logging and road-building (e.g., limiting clear-cuts and certain other methods of logging, prohibiting logging on very steep slopes, limiting logging adjacent to rivers), the ESA may limit these actions where species listed as threatened or endangered are located, the CWA may limit the amount of sediment that can run into streams from logging and road-building actions, and AIRFA and NHPA may limit land disturbance near sites of religious, cultural, or historical significance. In addition, some local governments, such as Santa Fe County, assert environmental and land use constraints on logging and road-building in national forests within the County's jurisdiction (e.g., limited or no land disturbance on steep slopes, no logging or road-building on ridgelines).

To measurably increase water yield requires removal of a significant percentage of basal area, that is, a substantial amount of tree harvest. In general, the greater the amount of harvest proposed, the more difficult it will be to comply with all of the laws discussed above. In addition, the planning and environmental studies for any major watershed thinning operation can be expected to take many months or even years in areas where there is significant opposition to a proposed project.

In addition to these legal constraints, there is the question, "who would own any surplus water that is generated by watershed management?" The quick answer to this question is that any additional water created by watershed management would simply become part of the public water supply and be subject to the prior appropriation system. Thus any increase in supply through land management activities would occasionally allow more junior appropriators to obtain their water which would not be the case without the management actions. No mechanism exists whereby the person or entity that funds a program to enhance the amount of runoff can claim any of that water except by obtaining a new, very junior permit.

5. Effectiveness in Either Increasing the Available Supply or Reducing the Projected Demand

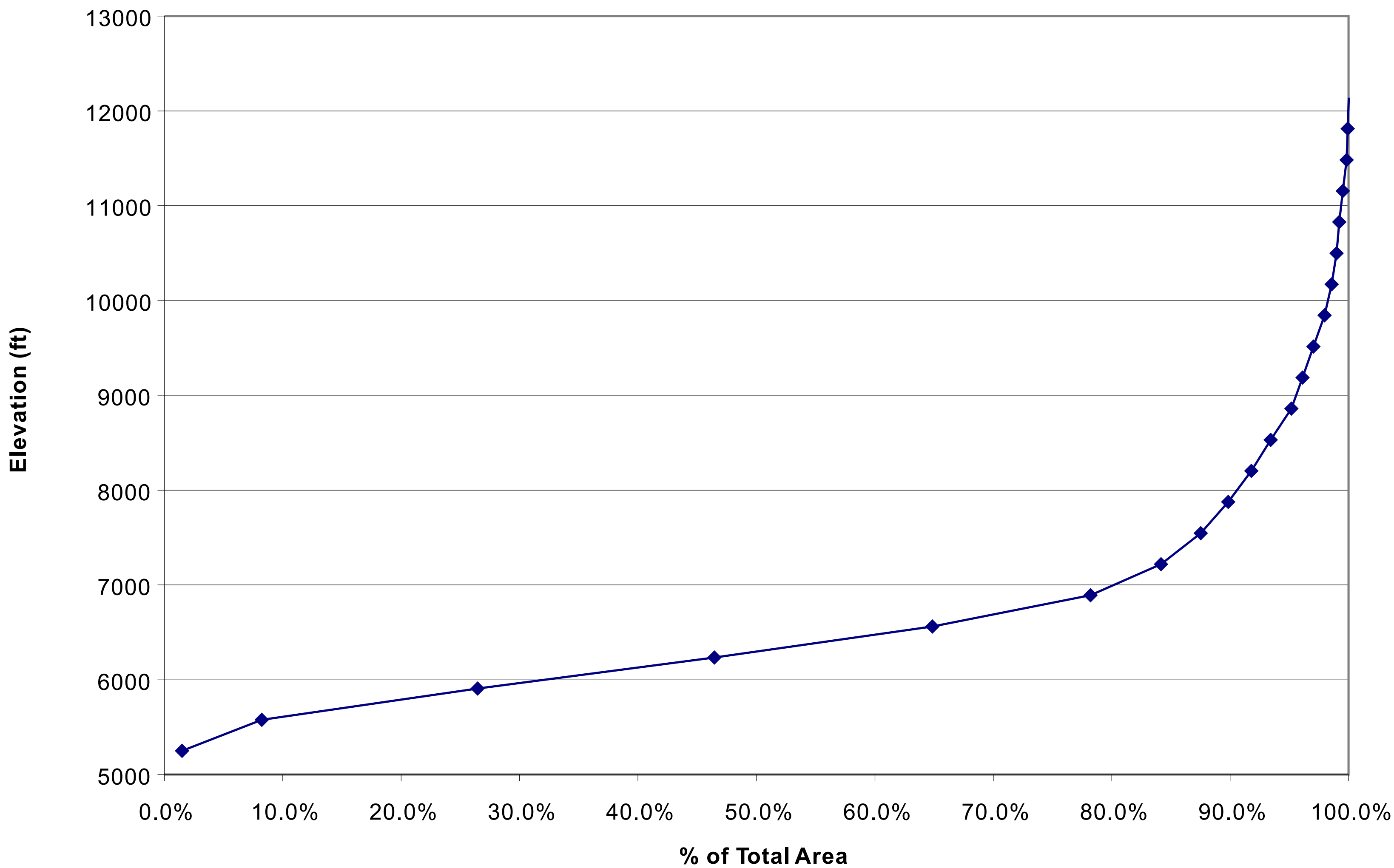
The technical, financial, and political issues associated with increased forest harvest suggest that the usable increases in water yield that might be gained from active forest management are likely to be relatively small. The potential gains could be quantified by sub-basin once one specifies the areas to be treated, the amount of basal area that would be removed per year, and the intervals between treatments. A relatively accurate estimate of the change in water yield would also require estimates of the monthly precipitation in each of the areas to be treated as well as the density and composition of the stands to be treated. Estimates of the potential adverse environmental effects would require specific information on the harvest method(s), slash treatment(s), and transportation network.

As a basis for comparison, only 24 percent of the 4,100-acre Coon Creek basin in the Medicine Bow National Forest was able to be harvested due to various management constraints, and the observed initial increase in seasonal water yield was 3.0 inches per unit area harvested, or 0.7 inches when averaged over the entire watershed (Troendle et al., 2001). This observed increase in water yield is consistent with other paired-watershed studies in the central Rocky Mountains. On a larger scale, Rector and MacDonald (1987) estimated that intensive management of national forest lands in the California Sierra Nevada could result in a sustained increase in water yields of only about 0.1 inch, as much of the land is not suitable for timber harvest or is subject to other management constraints.

Troendle and Nankervis (2000) estimated that the increased forest density on the 1.34 million acres of national forest land in the North Platte River basin has probably decreased water yields since the late 1800s by about 185,000 acre-feet per year. This equates to about 1.7 inches of water per unit area, or 2.0 inches of water per unit area of forest land. Approximately 54 percent of the total area, or 66 percent of the forested area, was classified as land suitable or potentially suitable for timber harvest. Intensive forest management on these lands could potentially yield an average of 55,000 acre-feet of additional water per year, or slightly more than one-third of the “losses” that are already occurring as a result of the increased forest density. The 55,000 acre-feet converts to 0.9 inch per unit of suitable forest land, or 0.5 inch per unit of national forest land.

These values from the North Platte study probably represent an upper bound on what might be expected from the forested areas addressed in this alternative, as two-thirds of the forested areas on national forest lands in the North Platte basin were classified as suitable or potentially suitable for timber harvest. Furthermore, species with a relatively high potential for increasing water yields (spruce-fir and lodgepole pine) accounted for nearly 85 percent of the forested area; ponderosa pine and aspen occupied only 13.5 percent of the forested area (Troendle and Nankervis, 2000).

Given the strong dependence of precipitation and forest vegetation on elevation, only some of the higher elevation sub-basins in the Jemez y Sangre region would have any potential to increase water yields through forest management. Thus the potential for increasing water yields can be evaluated simply by determining the proportion of the study area and each sub-basin that lies within different elevation zones. Figure 1 shows that 12.5 percent of the total study area lies above 7,500 feet, and less than 5 percent lies above 9,000 feet. Area-elevation curves (Appendix A) show that the sub-basins with at least 3 percent of their area above 9,000 feet are



JEMEZ Y SANGRE WATER PLAN

Hypsometric Curve for the Planning Area

Figure 1

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Pojoaque (16 percent), Santa Fe (4 percent), Los Alamos (3 percent), Velarde (4 percent), Tesuque (6 percent), Santa Cruz (20 percent), and Santa Clara (17 percent). Of these, the only sub-basins with significant surface water storage are Pojoaque and Santa Fe.

To provide an initial approximation of potential yield increases, the total acreage above 9,000 feet was computed (Table 1). A total of 83,000 acres in the region are above 9,000 feet, 74,000 of which are within the National Forest and 44,000 within wilderness areas. Assuming that all non-wilderness National Forest acreage can be treated, 30,000 acres could potentially be treated for improved yields (wilderness acres could possibly also be treated, but thinning in wilderness areas may encounter legal and logistical difficulties). Using the yield increases from previous studies in the Rocky Mountains of 0.7 to 0.9 inch (0.058 to 0.075 foot) per unit of land (Troendle et al., 2001; Troendle and Nankervis, 2000), the potential yield increase in the Jemez y Sangre region would be 1,750 to 2,250 acre-feet on average. More yield would be expected in the wet years and less would be expected in the dry years.

Table 1. Total Forested Acres above 9,000 Feet in the Jemez y Sangre Water Planning Region

Basin Name	Forested Acres above 9,000 feet	
	Total [a]	National Forest [b]
Los Alamos	7,773	6,941
Pojoaque-Nambe	14,460	15,252
Santa Clara	12,179	2,488
Santa Cruz River	28,356	29,093
Santa Fe River	8,284	8,854
South Galisteo Creek	1,771	3,540
Tesuque	3,878	3,963
Velarde	5,818	3,941
Total	82,520	74,073

[a] Includes land use classes (1) deciduous forest land, (2) evergreen forest land, and (3) mixed forest land.

[b] Does not include National Park Service lands (i.e., the small portion of Bandelier National Monument in the Los Alamos sub-basin).

As noted in Section 2.1, prescribed fires would not be expected to cause an increase in water yields because they would not eliminate much of the dominant tree canopy. From a purely hydrologic perspective, wildfires can cause a large increase in runoff, but this is usually regarded as a negative effect because high-severity-fires can greatly increase the size of peak flows and erosion rates both on the hillslope and in the stream channels (Robichaud et al, 2000). The combination of higher peak flows and large increases in sediment loads can have severe adverse effects on downstream water resources. Of course, there are other, obvious reasons why wildfires are not a viable management option.

In the piñon-juniper zone, management actions might change the flow paths of water, potentially causing some changes in water quality as well as the amount and timing of runoff. Without specific information on the proposed management actions, it is very difficult to provide explicit, qualitative predictions on the possible effect. Explicit quantitative predictions would also be very difficult (i.e., carry a very high degree of uncertainty) because of the spatial and temporal variability in key processes such as rainfall amounts and intensity, infiltration rates, and vegetative cover.

In general, efforts to reduce overgrazing and increase infiltration would reduce the amount of surface runoff and improve water quality. Most of this additional infiltrated water would be lost to evapotranspiration, suggesting that the reduction in surface runoff resulting from improved range conditions would be larger than the associated increase in groundwater recharge (Hillel, 1998). A reduction in surface runoff and an increase in infiltration could be expected to reduce the size of peak flows and possibly result in more sustained flows, depending on how much of the infiltrated water passes through the rooting zone and into the stream channel. The effect of management changes on hillslopes and riparian zones could potentially have a much greater effect on water quality than water quantity. Extensive outreach programs would be required, as a high percentage of the piñon-juniper lands are either private or under Pueblo jurisdiction. Rapid or extensive changes in piñon-juniper management over large areas will be difficult to achieve.

Similarly, the effect of efforts to restore or manage riparian zones will depend on the actions taken, the location and magnitude of these actions, and the site conditions where these actions are taken. In general, management actions to control exotic species should not be expected to have large effects on either water yields or water quality. The control and eventual eradication of exotic species is costly and requires more time, money, and expertise than most private landowners can summon, and an extensive outreach program will again be needed to treat a substantial proportion of the riparian areas. Programs using herbicides would engender considerable public opposition (e.g., the City of Santa Fe has an ordinance banning all class 1 herbicides within city limits). This means that mechanical treatments may become the primary management option for controlling exotic species.

6. Environmental Implications

The primary forest management options are some combination of commercial harvest, commercial and non-commercial thinning, and prescribed fires. While each of these treatments can be expected to increase erosion rates, studies have shown that the careful design of treatments and the use of best management practices can reduce the watershed-scale impacts of thinning or prescribed fire to very low levels (Troendle et al., 2001; Benavides-Solorio and MacDonald, 2001). In steeper areas, more expensive and less ground-disturbing yarding methods should be used to minimize erosion, and this may further increase the costs of any proposed management action. In general, one of the greatest concerns in forest management is the effect of the roads on runoff and erosion. If new roads have to be constructed, particularly in steep areas, this could have a much bigger effect on erosion rates than the various treatments, even though the latter will affect a much larger proportion of the watershed.

The change in forest density from any of these treatments will have different effects on different species. A more open forest will generally increase the amount of feed for large ungulates such as deer and elk, while a high canopy density will favor other species. In many cases, not enough is known about the habitat requirements of all the different species to accurately predict the likely effects of a proposed treatment. Another limitation is that the net effect of a treatment will depend on the relative value assigned to each species that is affected, and there may be considerable disagreement about those values.

The primary environmental advantage of reducing forest density is the reduced risk of high-severity fires. As noted in Section 2.1, high-severity fires in coniferous forests can increase runoff and erosion rates by one or more orders of magnitude relative to unburned conditions. These increases can have severe downstream effects in terms of flooding, reservoir sedimentation, and adverse effects on aquatic habitat.

An important concern in the case of prescribed fire and broadcast burning is the effect on air quality. Fires in forested areas produce a large number of particulates that are a hazard to human health. Smoke also has an adverse effect on visibility and visual esthetics. For this reason, prescribed burning programs often encounter considerable public resistance, and the agencies that regulate air quality may also have some reservations about issuing permits that may result in a substantial, albeit temporary, reduction in air quality.

Management goals for piñon-juniper woodlands are typically to increase the amount of forage and vegetative ground cover, reduce erosion, and re-establish native riparian species. More aggressive treatments such as chaining are generally not acceptable because of the excessive ground disturbance and potential increases in erosion. In general, efforts to improve range and reduce the impacts of grazing should be beneficial in terms of reducing erosion, enhancing habitat quality in the riparian zone, and improving water quality.

As in the case of the forest zone, any vegetative treatment in piñon-juniper woodlands will favor some species at the expense of others. The net effect will depend on the relative values of the species affected and the intended use of the area after treatment. In most cases, a reduction in tree density will increase the ground cover, thereby increasing the productivity of the land for grazing by large ungulates. The use of fencing and the more regular movement of livestock will help eliminate the tendency to overuse some areas and underuse others, with a net benefit on erosion rates and downstream water quality.

The removal of exotic species and the restoration of riparian zones are generally regarded as being environmentally beneficial. Whereas tamarisk stands provide little habitat for native fauna and are often dense, flammable monocultures, healthy stands of native riparian vegetation provide critical habitat for threatened or endangered species. A healthy riparian ecosystem is critical to the health of the adjacent stream in terms of temperature regulation, bank stability and sediment inputs, the input of organic matter and large wood, and the filtering of sediment and nutrients from overland flow.

7. Socioeconomic Impacts

The Jemez y Sangre region of northern New Mexico is distinguished by its rural and agricultural character, predominantly Indian and Hispano population, localized land-based economies, and pockets of persistent poverty. In particular, its Indian and Hispano populations represent some of the most unique cultures in the world, products of a long history of continuous human habitation, adaptation, and cultural blending. Land-based Indian and Hispano cultures still thrive, carrying on centuries-old cultural traditions that include distinctive land-use and settlement patterns, agricultural and irrigation practices, natural resource stewardship practices, social relations, religious activities, and architecture. An example is the ancient acequia tradition, which is vital both as a sustainable irrigation system for subsistence and market agriculture and as part of the social glue that holds together rural communities.

The survival of these deeply rooted local traditions is essential for the continuity of rural culture and communities and, in turn, for the local tourism industry, which is built in large part upon the singular cultural and historical personality of the region. Preservation of these traditions is therefore an important consideration in determining the socioeconomic and cultural impacts of regional water planning.

If it is successful in increasing surface water flows and groundwater infiltration, restoring and better managing forests, piñon-juniper woodlands, and riparian systems would have clear, if indirect, socioeconomic and cultural benefits. Stewardship of watershed resources is consistent with local history, land-based economies, and land-use traditions. Local communities and economies have always relied on the health of these fundamental resources. An increase in streamflow could help ensure adequate water for local acequias and other traditional uses and help recharge local domestic wells, while improved water quality could reduce irrigation system maintenance.

Restoration and better management of local natural resources that is successful in increasing streamflow could also benefit the outdoor-based tourism economy and all downstream communities, residents, and irrigators. In general, increasing available streamflow would probably reduce the cost of water for all users.

Given the general enhancement of environmental conditions and watershed productivity possible with the management options discussed herein, local rural residents are likely to be allies in these efforts. However, some of the management actions discussed herein may encounter local opposition. Piñon and juniper have long been the preferred fuelwood in New Mexico, and any program or action that would reduce or strictly limit access or supply might encounter local opposition. Grazing of sheep and cattle is also a tradition and a source of livelihood for local people within in the Jemez y Sangre planning region, and efforts to restrict or control the number of animals and the intensity of use in piñon-juniper lands and riparian areas could also meet with local opposition. In both of these cases, involvement of the local community in designing projects and prescriptions would largely alleviate any potential opposition.

In addition, prescribed burning programs often encounter considerable public resistance due to the adverse effect of smoke from the fire on visibility and visual esthetics. An extended period of prescribed fire will also raise issues such as the potential effect on tourism.

Designing restoration and management plans in collaborative consultation with affected local communities would help enlist local support and involvement and would integrate valuable traditional knowledge about local resources. Direct socioeconomic and cultural benefits would flow from contracting with local communities and small-scale local enterprises for forest thinning and fire management, riparian system enhancement, erosion control, and/or other stewardship work.

8. Actions Needed to Implement/Ease of Implementation

The impediments to initiating an active program to manage or restore forests, piñon-juniper woodlands, and riparian zones are many and difficult. Foremost among these are public concerns, which stem from a variety of different issues and perceptions. Efforts to harvest or thin forested areas typically meet with considerable local opposition, even though these actions might substantially reduce the risk of high-severity wildfires while having minimal effect on water quality. Efforts to alter the management of piñon-juniper woodlands and riparian zones are likely to be seen as a threat to traditional, local resource use, especially since large portions of these areas are in private hands or under Pueblo jurisdiction. Other than forest harvest, the costs of any proposed management action will probably be much greater than the estimated short- and medium-term economic benefits. As much of the cost will have to come from public funds, any proposed management actions will have to have clear public support. Programs to alter management or improve the condition of piñon-juniper woodlands and riparian zones may directly benefit only a small proportion of the population, again making it difficult to generate the support necessary for proposed management actions.

Efforts to restore the native vegetation and the natural geomorphic processes in riparian zones will often be constrained by the existing alterations of the flow regime and channel morphology. In many (if not nearly all) cases, the restoration of the natural flow regime cannot be achieved given the existing water needs and infrastructure of impoundments, diversions, and water rights. Extensive negotiations will be needed to balance human needs with ecological restoration. The restoration of riparian areas may also be impossible without extensive modifications to the existing channel morphology and in-channel structures such as diversions, bridges, reservoirs, riprap, and weirs for grade control. However, some local improvements to channel morphology can be made through grazing management and induced meandering. Monitoring of such projects is important to understanding changes in morphology.

9. Summary of Advantages and Disadvantages

Advantages of the forest, woodland, and riparian system management options discussed herein are:

- Reduced risk of wildfires
- Potential for small increases in water yield from forested areas
- Reduced surface runoff, surface erosion, and channel incision in piñon-juniper woodlands
- Improved range and riparian conditions in piñon-juniper woodlands and possibly an improvement in water quality
- Increased amount and quality of forage in all vegetation types
- Improved habitat for native riparian and aquatic species at lower elevations

Disadvantages of these options include:

- Considerable public opposition to forest harvest and thinning
- Poor cost-benefit ratios
- Limited potential to increase water yields and the likely timing of any increases
- Smaller water yield increases in dry years
- Potential decline in air quality and threat to human health from increased particulates from prescribed fires

- Financial and logistical difficulties of implementing management actions on private lands
- Restoration only partial in nearly all cases

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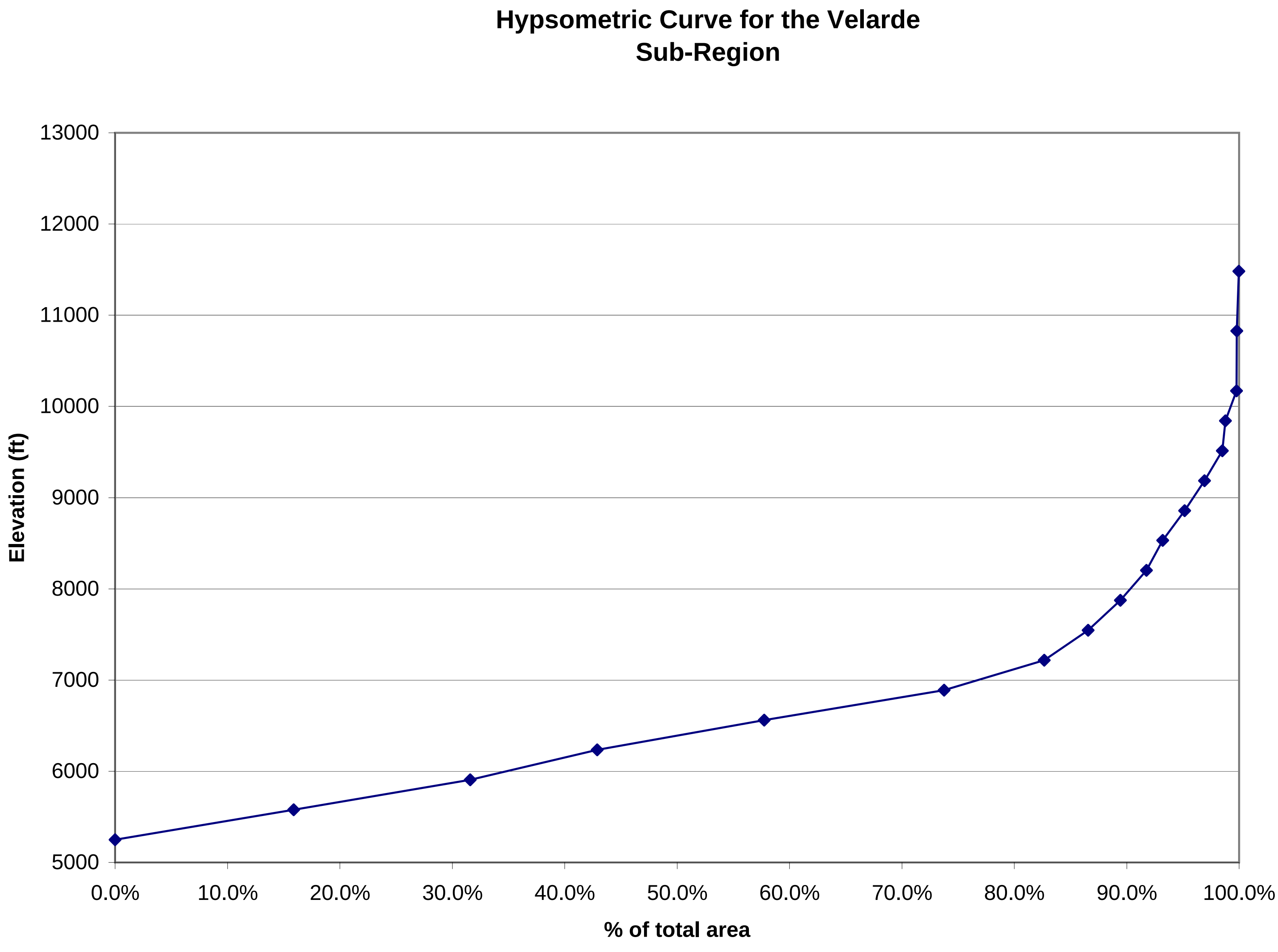
Appendix A

Hypsometric Curves



Hypsometric Curve for the Velarde Sub-Region
Elevation (ft)
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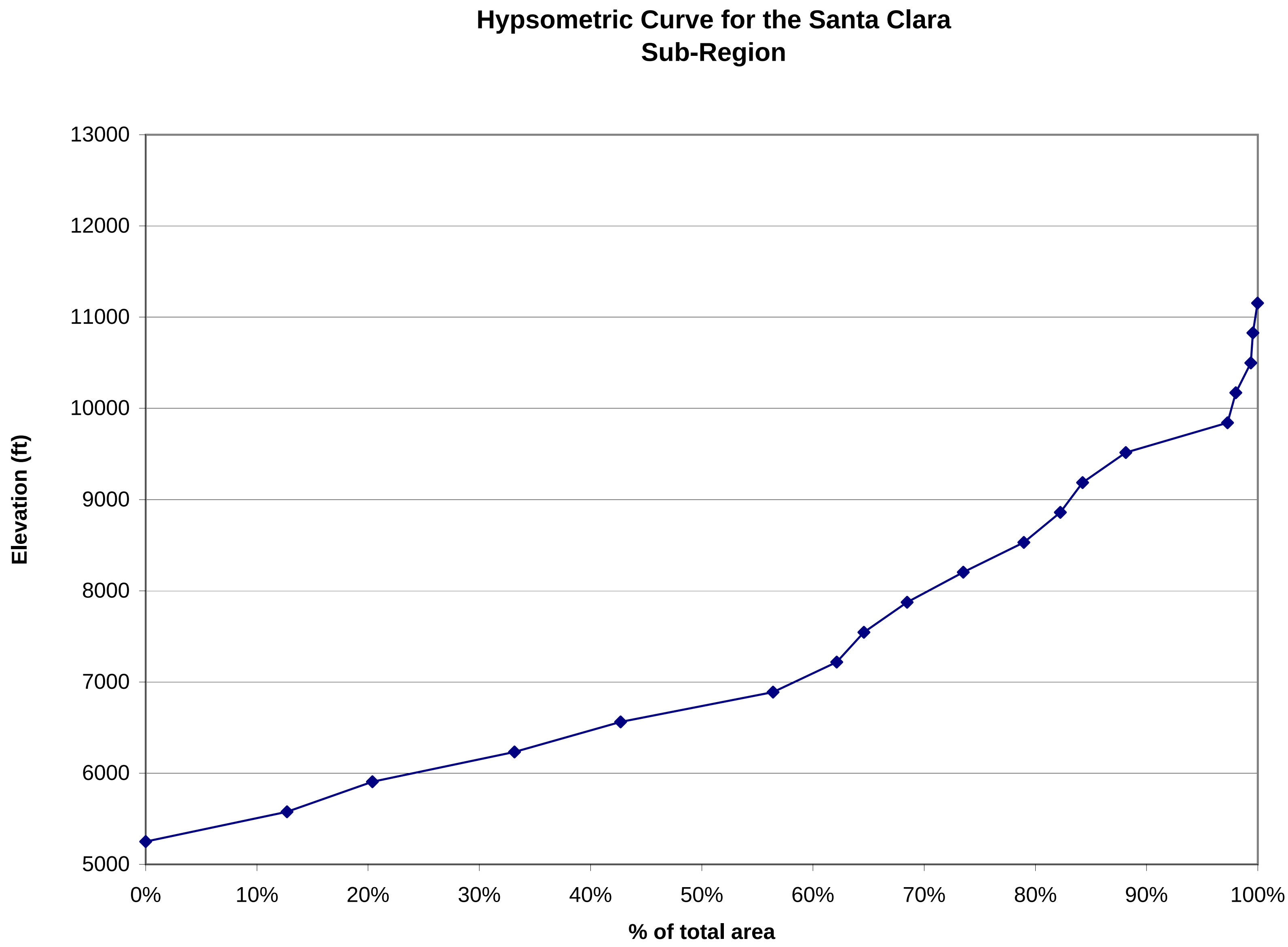
% of total area



Hypsometric Curve for the Santa Clara
Sub-Region
Elevation (ft)
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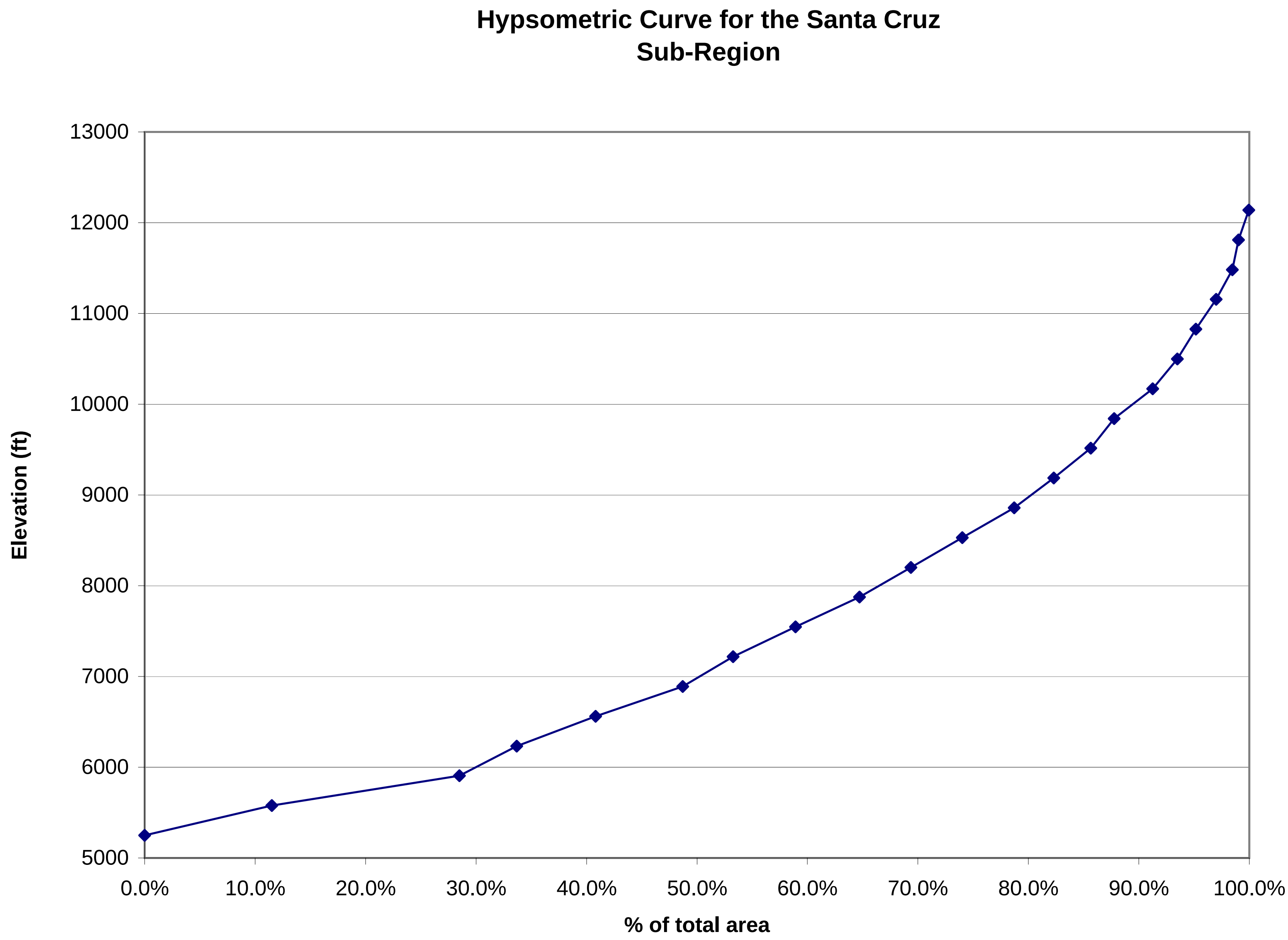
% of total area


Hypsometric Curve for the Santa Cruz
Sub-Region
Elevation (ft)
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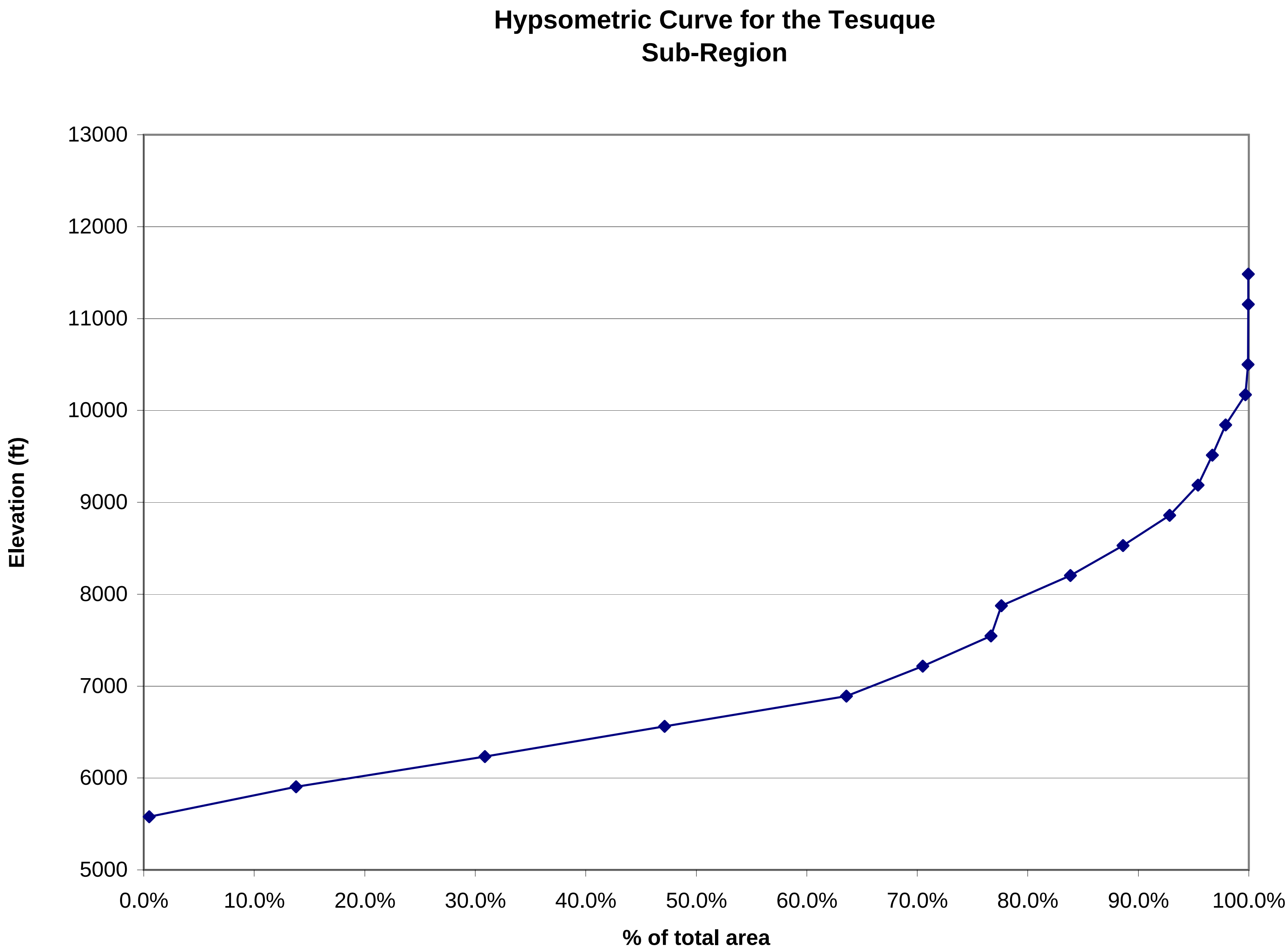
Hypsometric Curve for the Tesuque
Sub-Region
Elevation (ft)
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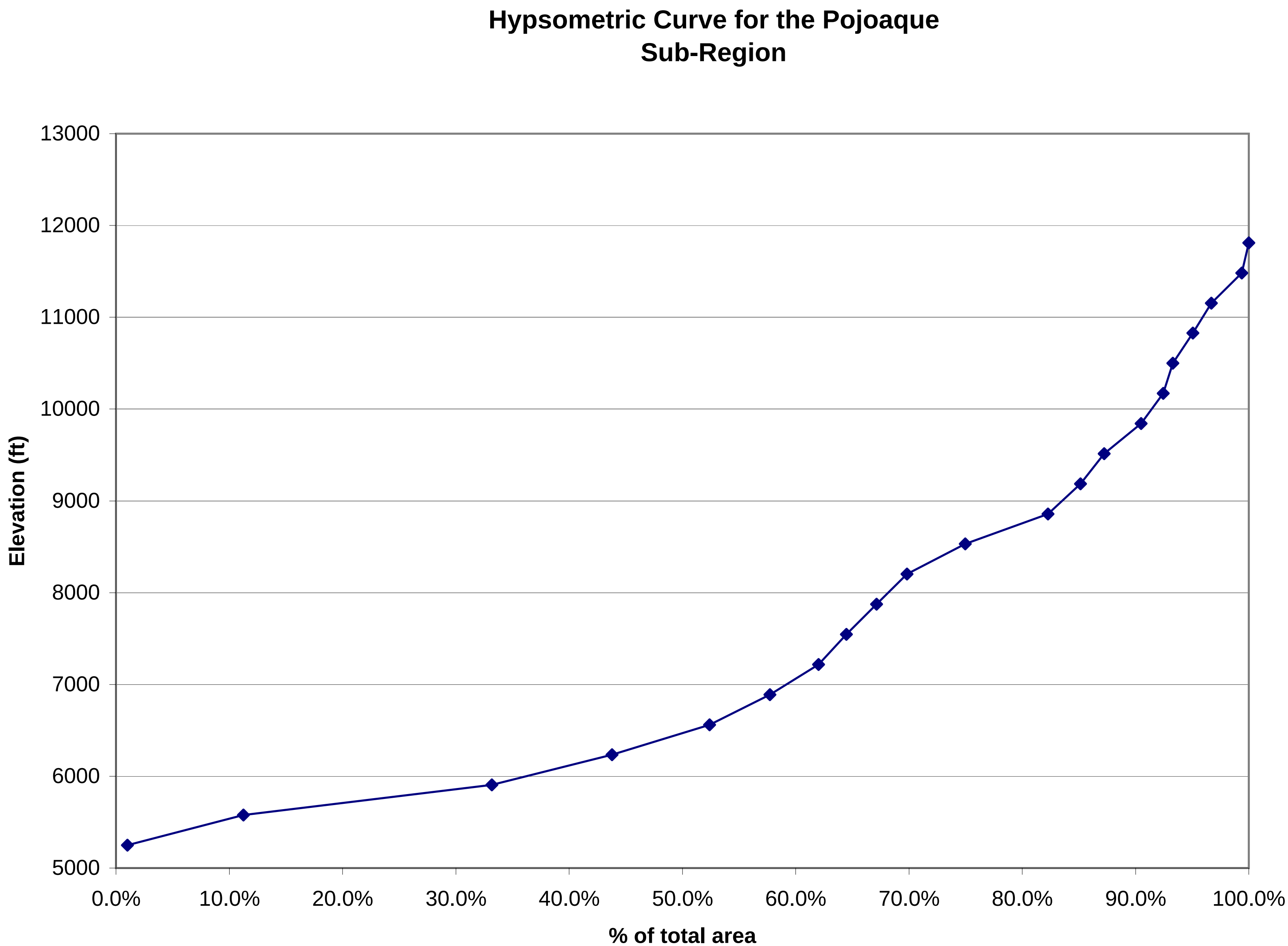
Hypsometric Curve for the Pojoaque
Sub-Region
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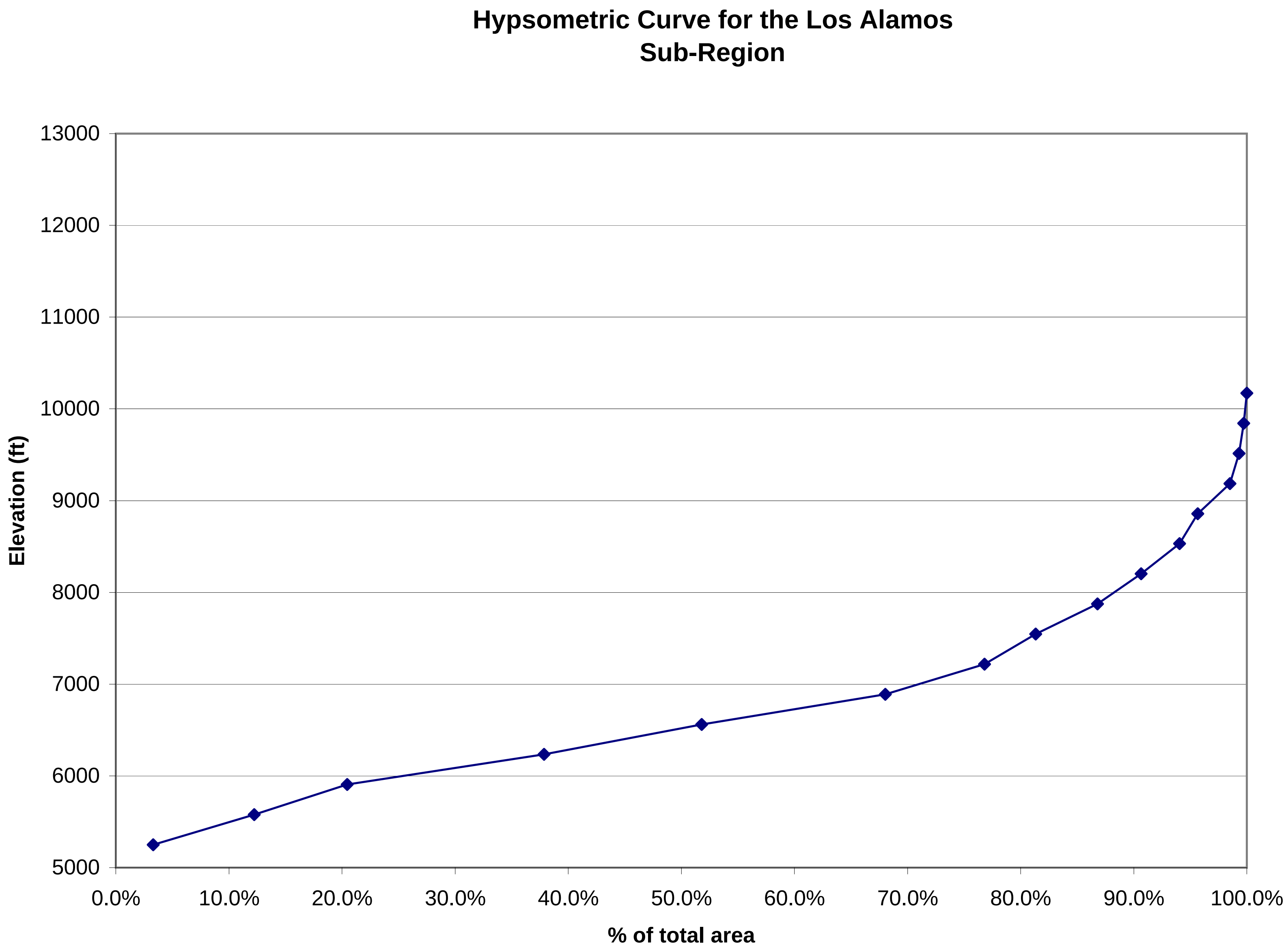
Hypsometric Curve for the Los Alamos
Sub-Region
Elevation (ft)
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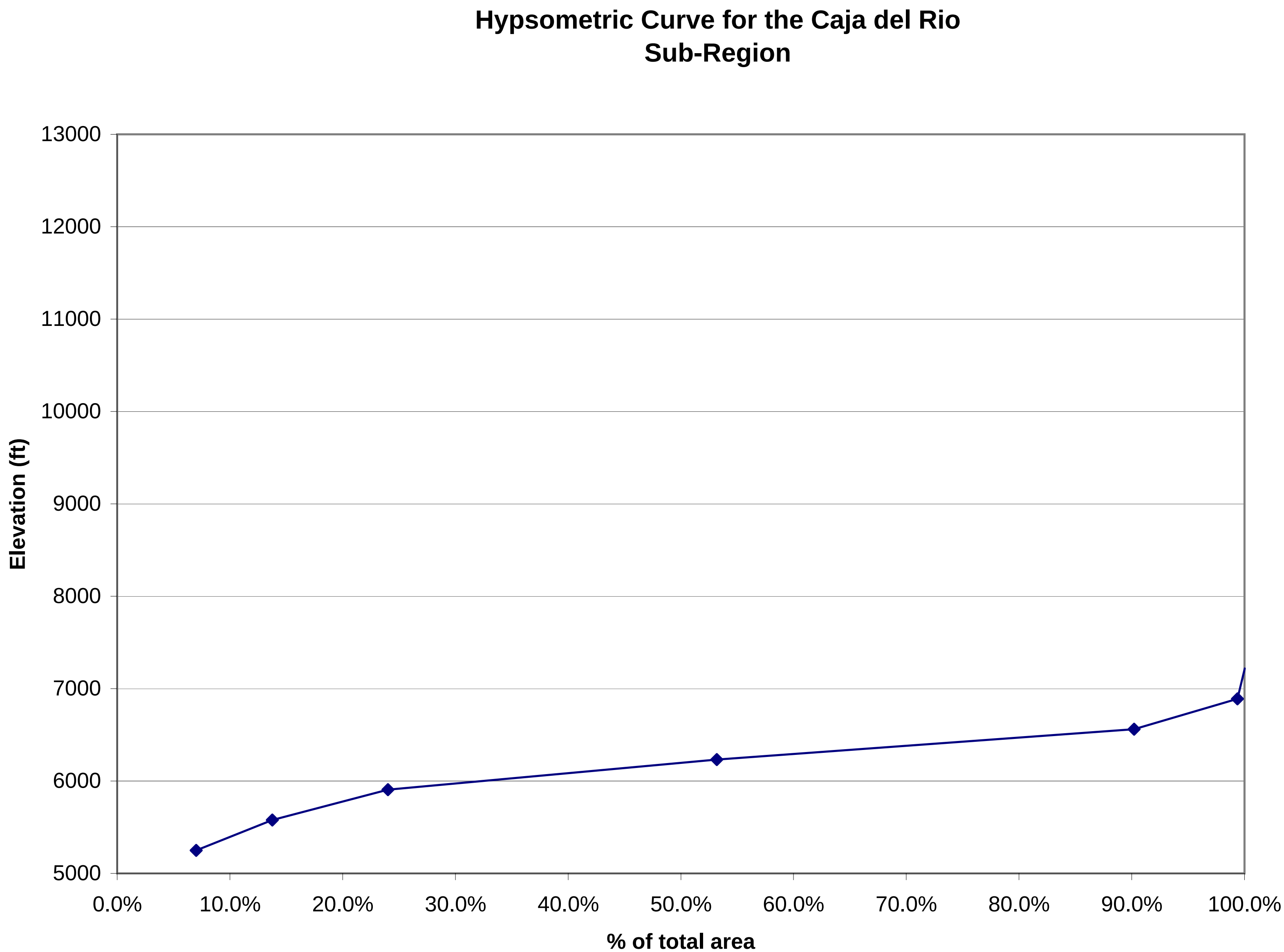

Hypsometric Curve for the Caja del Rio
Sub-Region
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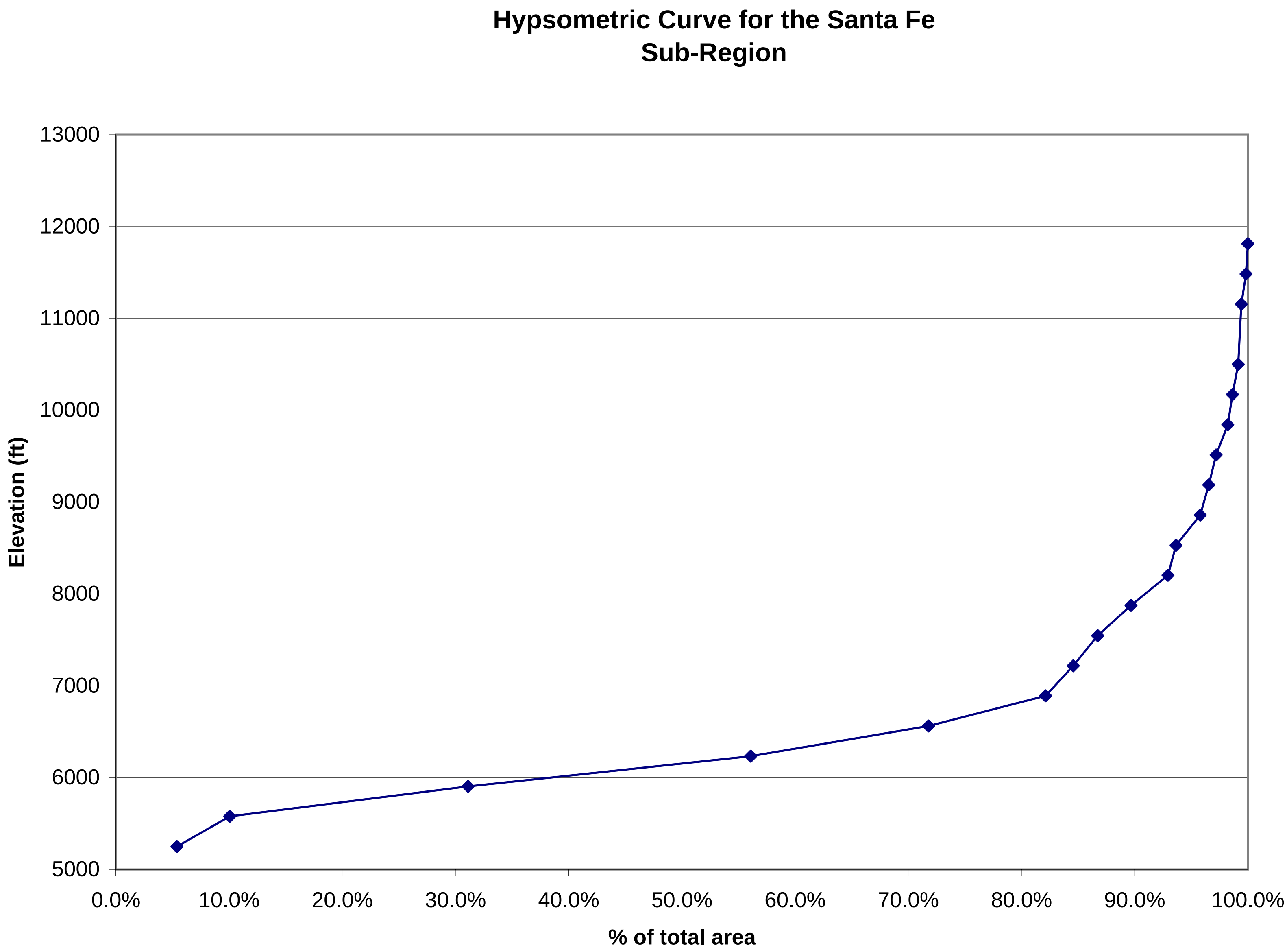

Hypsometric Curve for the Santa Fe
Sub-Region
Elevation (ft)
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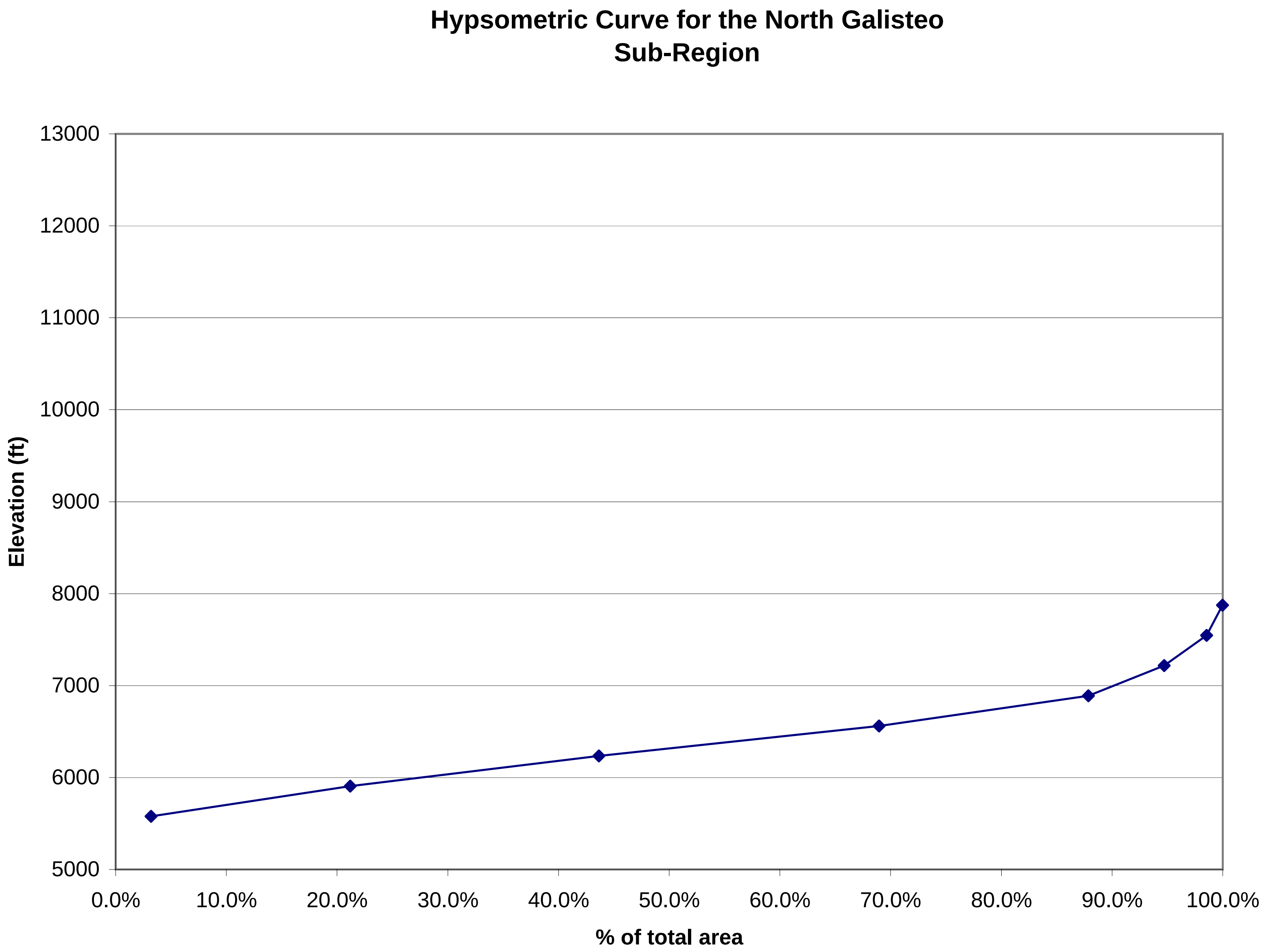

Hypsometric Curve for the North Galisteo
Sub-Region
Elevation (ft)
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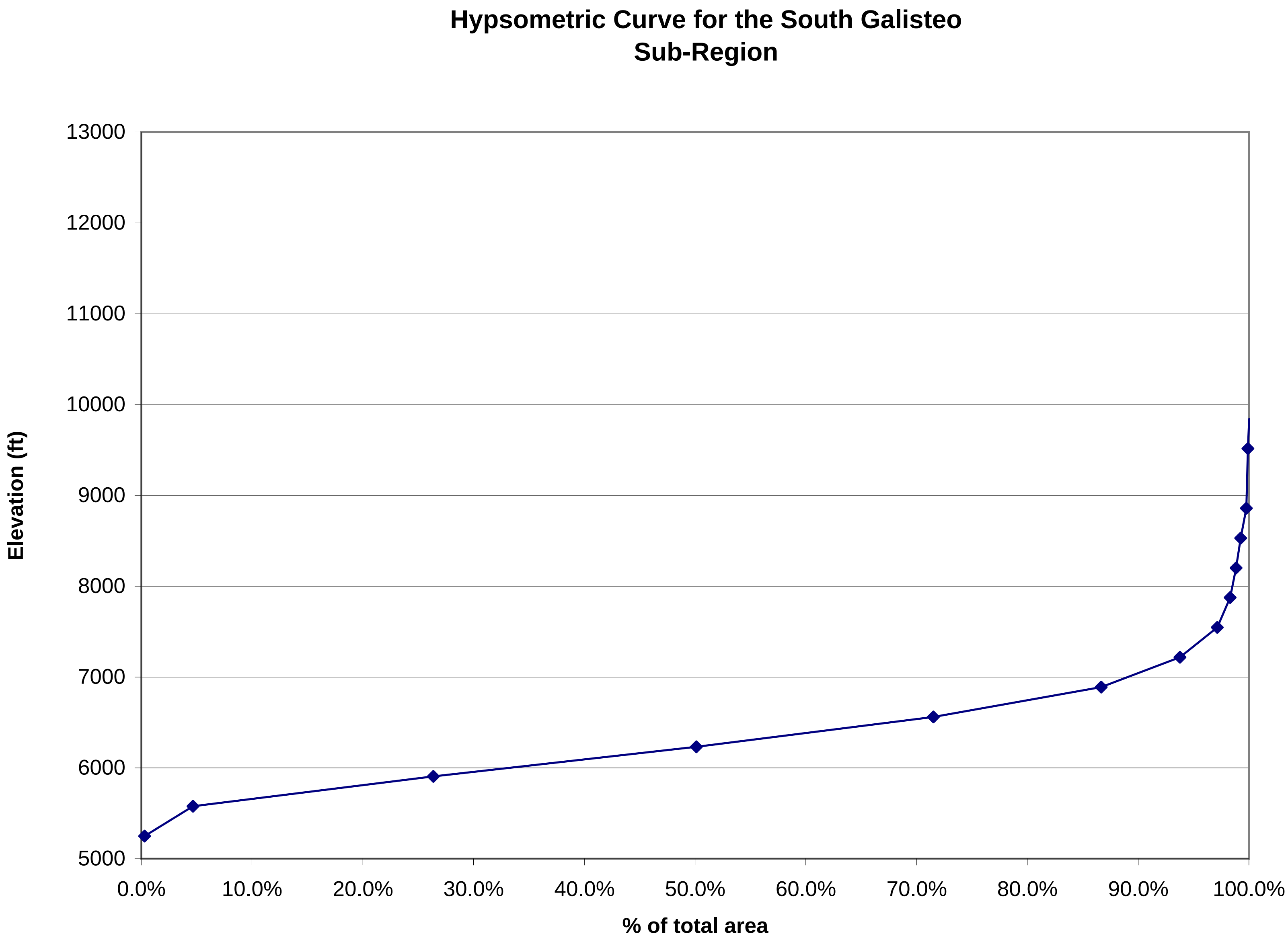
Hypsometric Curve for the South Galisteo
Sub-Region
Elevation (ft)
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